Editorial

Kinematic alignment in total knee arthroplasty: Does it really matter?

1. Introduction

The perfect placement of the femoral and tibial components is the most important predictor of the best clinical outcome in total knee arthroplasty (TKA). Clinical studies prove substantial variation in kinematic and functional performance within the TKA patient population. The variations in some situations are due to differences in implant design or surgical technique, the component alignment being considered as another important factor. These alignment errors in TKA have lead to the continuous evaluation of surgical alignment techniques. Many studies have shown that knee kinematics after TKA are still altered compared to the normal knee joint. But very little is evident to the patients regarding impairments and functional limitations. There are three alignment options in TKA, which includes anatomical alignment, mechanical alignment and the kinematic alignment. Mechanical and anatomical alignment assumes to keep the implants in an 'average' position in view that it changes the natural alignment of the limb and knee and causes uncorrectable knee instabilities.¹ Evidences have shown that a significant number of patients with mechanically aligned TKA continue to complain of pain, stiffness, instability and failure. Even though the primary aim of kinematic alignment is to recreate the normal knee joint kinematics and not to restore a neutral or 0° hip–knee–ankle axis. However, the kinematic alignment does not mal-align the hip–knee–ankle axis.

2. Alignment options in TKA

The normal knee joint line alignment is in 2°–3° of varus compared with the mechanical axis of lower limb. The main aim of all the alignment techniques is to achieve neutral alignment of the knee. This neutral alignment is rarely seen in healthy non-arthritis patients. A successful TKA is often based on reproducing the neutral knee alignment postoperatively. The normal movement of the knee joint is determined by the biomechanical interaction between the menisci, ligaments and the articulating surfaces of the femur, tibia and patella. There are three alignment philosophies of mechanical, anatomic, and kinematic alignment methods used in TKA. These alignment options are based on the distal femoral and proximal cuts taken according to the reference axis opted by the surgeon. Changes in the natural angle or joint level definitely cause alteration of the normal knee joint kinematics and ultimately results poor function.

3. Anatomical alignment

The anatomic axis of the lower limb is an axis in relation to the intramedullary canals of femur and tibia.² On antero-posterior

evaluation the anatomical and mechanical axis of tibia coincides exactly but in the femur it makes an angle of 5°–7°. The most important fact is the anatomic axis can deviate significantly depending on femoral or tibial angular deformities, and patient's hip angle.³ Femoro-tibial angle (FTA) is the angle subtended between the anatomic axes of the femur and the tibia on a weight-bearing X-ray.² The average value of the FTA is approximately 178° in men, and 176°–174° in women.² The FTA can be affected by various factors like axial limb rotation and flexion deformity.⁴ The FTA becomes more valgus with increasing valgus deformity.⁵

Hungerford and Krackow were described the anatomical alignment of TKA.⁶ They believed that the optimal TKA component position should anatomically recreate the joint line. Here the component alignment is 2°–3° of varus in relation to the mechanical axis of the lower extremity.⁶ The cuts are taken to mimic the natural knee by cutting the tibia at 3° varus to the anatomical (or mechanical) axis of the tibia and a distal femoral cut angle be made from the difference between the anatomic axis and the mechanical axis of the femur, is approximately 8°–9° of valgus.⁷ When this is combined, it gives a total alignment of approximately 6° of valgus that approaches the normal tibiofemoral angle. Also, this alignment provided for a joint line that is parallel to the ground during normal gait.⁶

4. Mechanical alignment

The mechanical axis of the lower extremity pass from the center of the femoral head to the center of the ankle joint.² In normal individuals the position of the mechanical axis usually passes just medial to the tibial spine. This can vary widely based on the patient height (decreased height results in increased axis deviation) and pelvic width (increased pelvic width in increased axis deviation).

The use of mechanical alignment in TKA was originally described by John Insall.⁸ Mechanical alignment is achieved by making an initial femoral cut perpendicular to the mechanical axis of the femur, which is followed by a tibial cut made perpendicular to the mechanical axis of the tibia. Insall believed that mechanical alignment was the superior method. His philosophy was in anatomically aligned knee, because of the increased forces across the medial joint component, lead to medial tibial plateau fixation failure.¹ Insall pointed out that even though the joint loading forces between compartments are even during the stance phase, it will be uneven during the gait phase due to a "laterally" directed ground reaction force.¹ He also argued for the 3° of external rotation of femoral component to balance the flexion and extension gaps.

5. Kinematic alignment

In kinematically aligned TKA, three axes govern the movement of the patella and tibia with respect to the femur. The better understanding of these axes is the key to kinematically aligning a TKA. The primary axis is a transverse axis which passes through the center of a circle fit to the articular surface of the femoral condyles from 10° to 160° of flexion. The tibia flexes and extends around this axis.⁸ Through the second transverse axis in the femur about which the patella flexes and extends. Second axis is parallel, proximal, and anterior to the first axis. The third axis is a longitudinal axis in the tibia about which the tibia internally and externally rotates on the femur. The third axis is perpendicular to the first and second transverse axes.⁸ Although each of the three axes is aligned parallel or perpendicular to one another, none are aligned orthogonally to the three anatomic planes, which mean that the axis cannot be found with imaging studies performed in the sagittal, coronal, and axial planes.⁹ So it is to co-align the transverse axis of the femoral component with the primary transverse axis in the femur about which the tibia flexes and extends is the main goal of kinematic alignment of the femoral component.⁸

This is done by shape-matching the femoral component to the articular surface of the femur. The femoral component should co-align with the primary transverse axis, which is important for the restoration of the normal interrelationships among the three axes.¹⁰ Kinematically aligning the tibial component involves several steps unlike the femoral component placement. The first step is to align the anterior-posterior axis of the tibial component perpendicular to the transverse axis of the femoral component.¹¹ The second step is to align the tibia to the tibial component, which is based on the assumption that the internal-external rotational relationship between the femur and tibia is normal. The final step is aligning the center of the tibia under the center of the tibial component. This is planned with the help of a software which creates a 3-dimensional model of the arthritic knee from a non-weight bearing MRI or computed tomography arthrogram of the knee. Additional software programs help to transform the arthritic knee model of the patient to a normal knee model. Then it kinematically aligns the components by shape-matching the best-fitting femoral and tibial components to the normal knee model. The 3-dimensional position of each component is then transferred by the software, from the normal knee to the arthritic knee model. Finally the patient-specific cutting guides are made to fit the patient's femur and tibia accordingly.^{12,13}

By comparing the symmetry of the thickness of the bone resections the kinematic alignment of the femoral component can be confirmed intra-operatively. Then restoration of motion and balancing the TKA is simplified by a stepwise algorithm of removal of osteophytes, adjusting the plane of the tibial cut, releasing the posterior capsule from the femur, and lateralizing or medializing the tibial component. Here the undesirable consequences are lessened by customizing the position of the implants with kinematic alignment.

Coronal alignment is definitely a factor in deciding the outcome of TKA, though it may not be the most important factor but may serve to compound failure from other causes.¹⁴ The principle of mechanically aligned TKA is to restore the neutral mechanical axis which will help to improve the implant durability and patient's function following surgery.¹⁵ In a study by Fang et al.,¹⁶ three alignment groups were selected and it was found that patients who had alignment between 2.4° and 7.2° of valgus had the best overall survivorship. They also noted that varus knees might failed due to medial tibial collapse, and valgus knee failed commonly because of ligamentous instability.

Jeffery et al.¹⁷ radiographically assessed the mechanical axis of TKA and reported that when the axis passed through the middle

one-third of the prosthesis, which resulted in a 3% rate of loosening. While as the axis shifted either medial or lateral, the loosening rate was increased to very high value (24%). There are many reports that, patients who achieved mechanical alignment within 3° of the mechanical axis had a significant increase in International Knee Society Score and Short-Form 12 physical scores compared with patients who did not. Despite the common belief among orthopedic surgeons that a mechanically well-aligned TKA will result in improved outcomes. But many studies have challenged this concept.

The conventional and computer navigated system uses mechanical alignment TKA have no bearing on the kinematics of the knee.¹⁸ Even among the perfectly mechanically aligned TKA groups have a 20% prevalence of patient dissatisfaction.¹⁹ Studies show following mechanically aligned TKA with conventional instruments, one out of five patients is not satisfied because of continued pain and poor function.¹⁹

There was no functional or patient satisfaction correlation between the two functional arc alignment groups of 3° or less and 3° or more.²⁰ However, they observed that in patients who had more than 3° of alignment has significantly increased difficulty with activities of daily living. Another interesting observation in 15-year follow up study between the prostheses place within 3° of varus or valgus compared with the prosthesis aligned outside this range that there were no differences in the estimated survivorship.²¹

Several studies have shown that there are a significant number of healthy asymptomatic adults do not have a neutral mechanical axis but mechanical alignment TKA believes on this non-existing zero axis.

So the mechanically aligned TKA will kinematically mal-aligns the knee and ultimately causes early failure.⁷ Although there is a wide belief that a neutral mechanical axis will result in better longevity of TKA, the mid- or long-term scientific support for this contention is surprisingly weak.⁹ Recently many reports have been highlighted challenging the superiority of neutral mechanical alignment.

Regarding the survival of implants, Morgan et al. reviewed the outcomes of 197 KinemaxTM TKAs and found no difference in revision rate among those in neutral, varus or valgus alignment postoperatively.²² Hence many researchers have explored the cylindrical axis of the knee²³ and then came the concept of kinematic alignment.²⁴ This is considered to be a 3-dimensional alignment of components, whereas the other two were 2-dimensional only.²⁵ The goal of this alignment method is to achieve a "more natural" knee kinematics.²⁶ The kinematic alignment reestablishes the normal obliquity and the pre-arthritic level of joint line. This is considered as the reasons for the good improvements in clinical outcomes, greater ranges-of-motion, and better patient satisfaction.²⁶ A change in the natural angle and level of joint line causes abnormal kinematics; consequently there will be instability, stiffness, wear and component loosening.²⁷ In kinematically aligned TKA the bony cuts restore the natural angle and level of joint thereby minimizing the complications.

The kinematic alignment concept is traced to Hollister and colleagues' were done a lot of classic research on the kinematics of the knee and who highlighted the biomechanical rationale for kinematic alignment.⁸ Before the practice of kinematic alignment, the TKA were performed mainly on the mechanical alignment principles. Kinematic alignment works on different principles for placing the components. Here, co-aligning the transverse axis of the selected best-fitting femoral component with the primary transverse axis in the femur, removing osteophytes to restore ligament length motion and stability, and placing the tibial component perpendicular to the transverse axis in the femur. Loss of flexion and extension, pain, stiffness, instability and prolonged

recovery associated with mechanical alignment are not seen with kinematically aligned knee [.../Users/yathra/Desktop/doubts/KINEMATICS/Mechanical, Anatomical, and Kinematic Axis in TKA Concepts and Practical Applications.htm – CR347). Studies have shown that releases of the collateral ligaments are not needed with kinematic alignment, which could be the reason why kinematically aligned TKA restores more normal contact kinematics than mechanical counterpart.²⁸

A level I prospective randomized control study which compared the function, patient satisfaction and flexion by Dossett et al. shows significantly better results in kinematically aligned TKA.²⁵ There was a significantly better WOMAC and KSS scores in kinematic alignment group compared with the mechanically aligned counterpart. Although the kinematic alignment group demonstrated significantly better overall results, more outliers with poor outcomes were also seen in this group.²⁹ This study also shows that, restoring the pre-morbid flexion-extension axis offers a better overall functional results and the kinematic alignment is a favorable technique for TKA. It is found that the contact mechanics in kinematically aligned TKA had normal motion hence have high function.²⁸

The added advantages of kinematically aligned knees are shorter operating and recovery time and earlier return to the daily routines. Moreover blood transfusions are infrequent, probably because the collateral and retinacular soft tissues are not released. Fat embolic incidents have not been occurred because intramedullary rods are not at all used.

7. Conclusion

The goal of a successful TKA is to achieve good alignment of the femoral, tibial, and patellar components. Faulty joint alignment can result in increased implant stress, poor functional outcomes, and early failure. The better survivorship of the mechanically aligned TKA might be the result of better balancing of the knee and restoration of normal kinematics rather than the modern implant design or instrumentation. Kinematic alignment does not mal-align the natural hip–knee–ankle axis of the patient. Kinematically aligned TKA stand as a superior alternative to the mechanically aligned TKA because it offers a better patient satisfaction and joint function. As of now, the kinematically aligned knee restored high function with no catastrophic failure because it has less abnormal kinematic contacts. All these factors promote this wonderful concept as a worthy alignment option for a better TKA.

Conflicts of interest

The author has none to declare.

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